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A 13 cm Fully Transistorized Transverter

All previously described and published 13 cm transmitters operated exclusively with high local oscillator powers. Power mixers, such as with a diode BXY 28 (1), or with a tube 2C39 (2) require local oscillator powers in the order of 1.5 to 2.5 W. In order to achieve such power levels, several varactors, as well as a power amplifier in the range of 350 to 500 MHz are used. The mechanical but also the financial expense are very considerable. For this reason, a transmitter was designed that could be manufactured at low cost and with low mechanical needs.

BLOCK DIAGRAM

As can be seen in Figure 1, the transverter comprises five modules, the interdigital mixer and the IF-preamplifier are also given.

The local oscillator module (DF5QZ 001) provides an extremely low spurious signal to the transmit mixer (002) The oscillator signal for the receive converter is taken at this point via a further BNC-connector The receiver comprises an interdigital mixer with IF-preamplifier as described in (3).

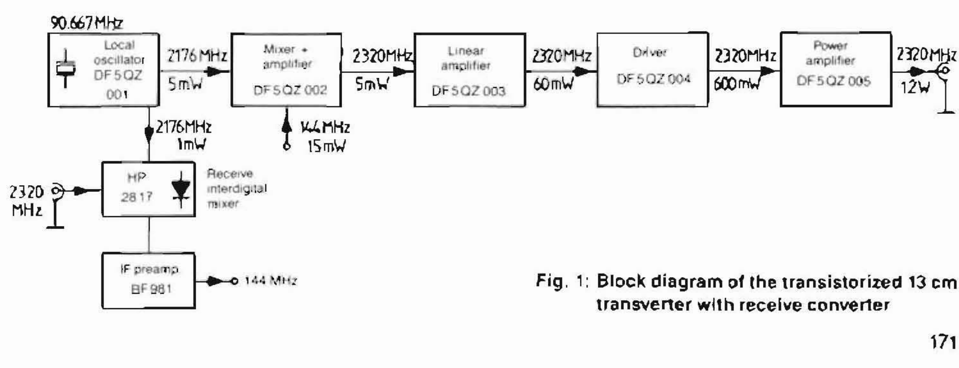

Fig. 1: Block diagram of the transistorized 13 cm transverter with receive converter

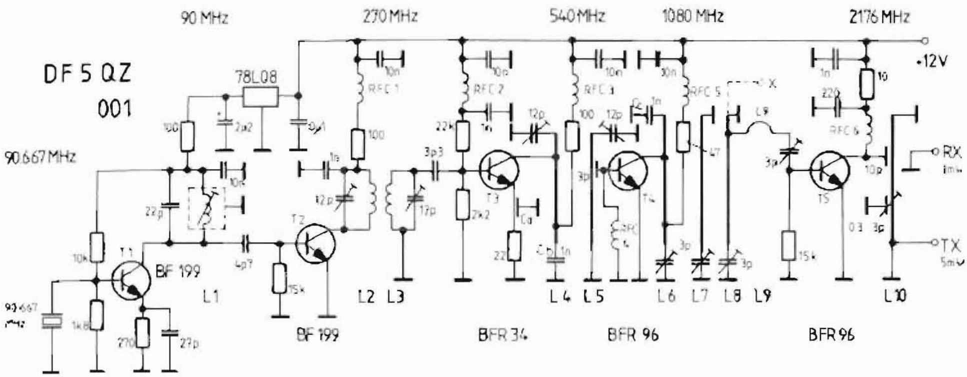

Fig. 2. Local oscillator module DF5QZ 001

The transmit mixer is in a push-pull circuit, which converts up the oscillator signal and the 144 MHz drive signal to the required frequency range of 2320-2322 MHz. Two linear amplifier stages are provided to amplify the required signal by 10 dB before feeding it to the third stage.

DF5QZ 003 is equipped with a further two-stage linear amplifier, which supplies sufficient power for driving the driver module (004). This module is followed by a low-power amplifier (005), that provides an output power of 1 to 1.2 W.

1. LOCAL OSCILLATOR MODULE

The crystal oscillator of this module **(Figure 2)** oscillates at 90.666 MHz. This is multiplied by twelve to provide 1088 MHz (the frequencies given in the circuit diagram are rounded down). This is followed by a printed 3-stage filter, which ensures a clean spectrum. The following frequency doubler stage is driven via the series resonant circuit comprising L 9 and generates the required local oscillator frequency of 2176 MHz. The frequency doubler transistor T 5 operates into a $\lambda/2$ air-spaced stripline circuit (L 10). In order to obtain very high efficiency and good selectivity, a printed inductance was not used here.

The output signal for the transmit mixer was tapped off at the 50 Ω point of the circuit, whereas the coupling for the receive mixer (RX) is achieved via a coupling link in the direct vicinity of the output circuit.

This local oscillator can also be used for the 23 cm band by replacing the crystal with a 96.000 MHz type and leaving out the last stage comprising T 5. The output frequency of 1152 MHz is tapped off at the 50 Ω point of L 8 (which is usually soldered to L 9). The 3-stage filter comprising L 6 – L 8 is highly selective, which means that one is able to obtain a very clean local oscillator signal for 1296 MHz equipment having an IF of 144 MHz.

1.1. Components

L 1:	Coil set blue/brown
L 2:	2 turns of 1 mm dia. silver-plated copper wire wound on a 6 mm former, self-supporting
L 3:	as L 2
L 4 – L 8:	printed on DF5QZ 001
L 9:	Bent wire, link, made from 1 mm dia. silver-plated copper wire, bent around a 6 mm former, 10 mm high
L 10:	Brass-plate strip, 6 mm wide, 35 mm total length, each end bent down by 4 mm

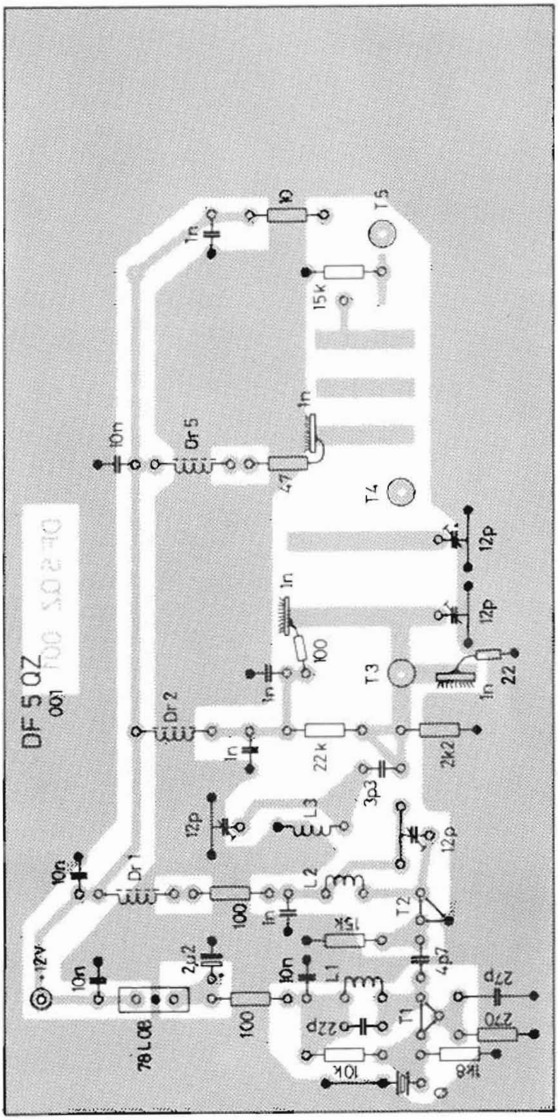

Fig. 3:
PC-board DF5QZ 001 showing component locations

C_a, C_b, C_c: Chip capacitors, approx. 1 nF; press into slots on the board!

Trimmers: 2 – 12 pF: plastic foil trimmer, yellow (Philips)

0.5 – 6 pF: plastic foil trimmer, grey (Philips)

0.3 – 3 pF: ceramic spindle trimmer (Philips)

RFC 1 – RFC 5: 2 turns of approx. 0.4 mm dia enamelled copper wire wound in a ferrite bead

RFC 6: 2 turns of 1 mm dia. silver-plated copper wire wound on a 2.5 mm former, self-supporting

Metal case, 74 x 148 x 50 mm (cover dimensions x height)

1.2 Construction

A double-coated PC-board DF5QZ001 was designed for accommodating the local oscillator module (Figure 3). The dimensions of this board are 146 mm x 72 mm and it can be mounted in the given metal box.

The upper surface is in the form of a ground surface, which is only removed around those connections that are not grounded. Since the ground surface of the base can affect the output power, it is necessary for the cover on the conductor lane side to be soldered all around the edge. The component side of the board does not require a cover.

The board is firstly completed from the component side of the board, and the 3 pF spindle trimmers (horizontal) are soldered from the conductor side. It is important that the ground connections of these trimmers be connected with the ground surface of the component side of the board. The output circuit L 10 is also mounted from the conductor side. The cold ends of L 6, L 7, and L 8 must be "through-contacted" to the component side of the board using a copper strip. Figure 4 shows this critical part of the board.

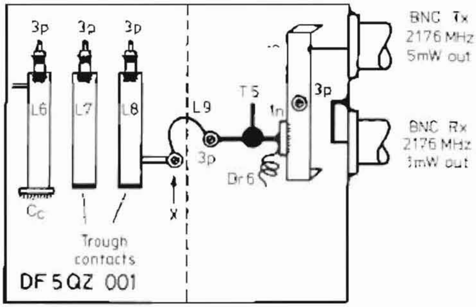

Fig. 4: Construction details regarding the last frequency doubler on DF5QZ 001

1.3 Alignment Details

The frequency is checked after the crystal oscillator has locked in. The subsequent frequency tripler stage is checked with the aid of a dipmeter or frequency counter since it is possible for the second harmonic to be aligned instead of the

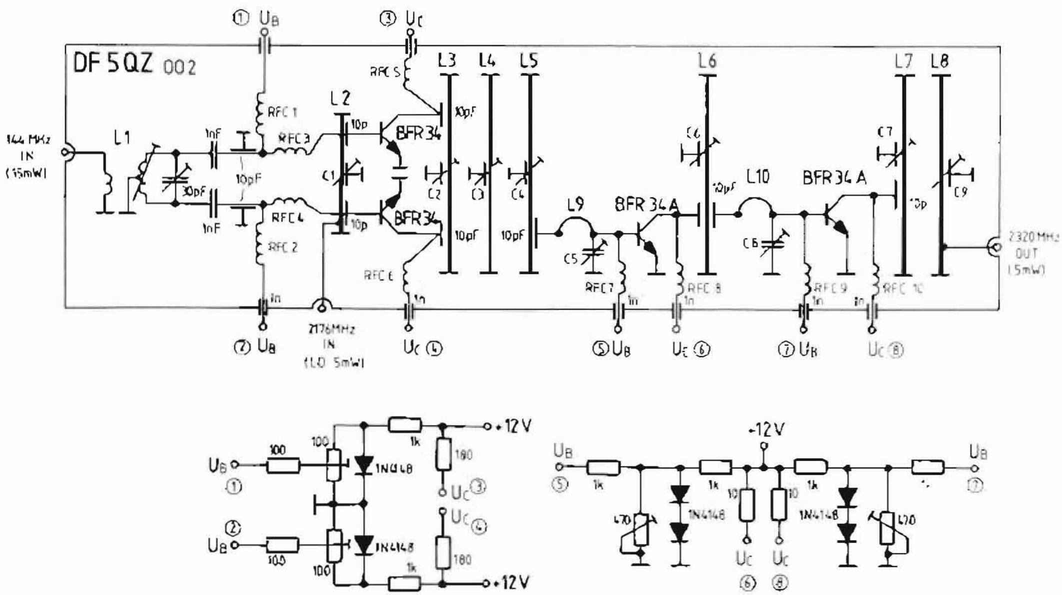

Fig. 5: Push-pull mixer, 2-stage linear amplifier, and bias voltage supply

third. If the required frequency is present at this position, it is possible for the subsequent stages to be aligned for maximum output power. An incorrect alignment is virtually impossible since these circuits have been designed exactly. The alignment of the λ/2 circuit to the final frequency does not present any problems and can be carried out easily.

2. TRANSMIT MIXER

The mixer module comprises two BFR34A as push-pull mixer and two further transistors of this type as selective linear amplifiers (see **Figure 5**). It is also enclosed in a metal box, and the stages are built up in separate chambers using intermediate panels.

Various attempts to use these SHF standard transistors, type BFR34A, in printed circuits on epoxy glassfibre boards have not been successful. Unfortunately no attempts were made using PTFE board material due to the high costs envolved. It seems, however, that the expected performance is not worth such expense.

The construction recommended here uses λ/2 air-spaced striplines (**Figure 6**), and it seems that the maximum values of the semi-conductors have been achieved at 2300 MHz. In addition to this, the excellent selectivity of air-spaced stripline circuits together with the chamber construction ensures a clean output signal from this module.

The mixer version recommended here with its specific tuning of the collector circuit to the required frequency corrects many old opinions that a conversion to 2300 MHz with a BFR34A is no longer possible. The problem was not the BFR34A, but the printed construction of the modified DF8QK type. In those cases, due to the undefined selectivity, the 16th harmonic of the 2 m drive signal was radiated after being amplified in the transmitter.

This problem was not present here, and the subsequent filter improves the output signal further so that spurious waves are more than sufficiently suppressed. Furthermore, an important point is the exact matching to the subsequent transistor input with the aid of the series circuit comprising L 9.

2.1 Components

L 1:	5 turns of 1 mm dia. silver-plated copper wire wound on a 5 mm dia. coil former with VHF-core; Input coupling: 2 turns of insulated wire wound symmetrically to the center of L 1
L 2 - L 8:	Brass strips, 6 mm wide, length before bending = 35 mm, bent down 4 mm at both ends at an angle of 90°

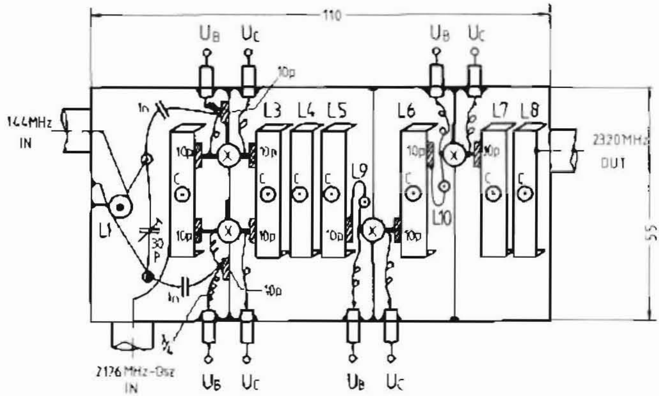

Fig. 6: Construction of module DF5QZ 002 (mixer and linear amplifier)

L 9, L 10. Bent wire from 1 mm dia. silver-plated copper wire, bent over a 6 mm former
RFC 1, RFC 2: λ/4 choke for 145 MHz = 50 cm. of 0.4 mm dia. enamelled copper wire wound on a 4 mm former, self-supporting
RFC 3 – RFC 10 2 turns of approx. 0.4 mm dia. enamelled copper wire wound on a 2.5 mm former, self-supporting
C 1 – C 9: Ceramic miniature spindle trimmer 0.5 – 3 pF (Philips)
Coupling capacitors Ceramic disks of 10 – 3 pF
Feedthrough capacitors: approx. 1 nF
Metal box: 57 x 111 x 30 mm

2.2 Construction Details

Construction is commenced by making the holes for the spindle trimmers in the base of the box as shown in **Figure 6**. After this, the λ/2 circuits are soldered into place with the holes for the trimmers at the center, after which the intermediate panels are also soldered into place. The side panels are provided with the holes for the BNC-connectors and feedthrough capacitors. After assembling the base plate with the side panels, it is possible for the transistors, chokes, disk capacitors, as well as the 144 MHz circuit to be mounted and then soldered into place.

The network for adjusting the mixer balance and the operating points is provided outside of the box on a small Vero boards. This can be srewed below the mixer module afterwards. **Figure 7** shows a photograph of the author's prototype.

2.3 Alignment

Firstly connect the operating voltage and local oscillator signal; measure the voltage drop across the collector resistor of one of the mixer transistors (between +12 V and point 3 or 4). If the output circuit of the oscillator module DF5QZ001 and the input circuit of the mixer are in resonance, the voltage drop will increase clearly. The circuits should be aligned for maximum voltage drop.

This is followed by injecting a 144 MHz drive signal (max. 15 mW!), and measuring the voltage drop across the collector bias resistor of the mixer transistor. This drive will cause a further increase of voltage. This is brought to maximum

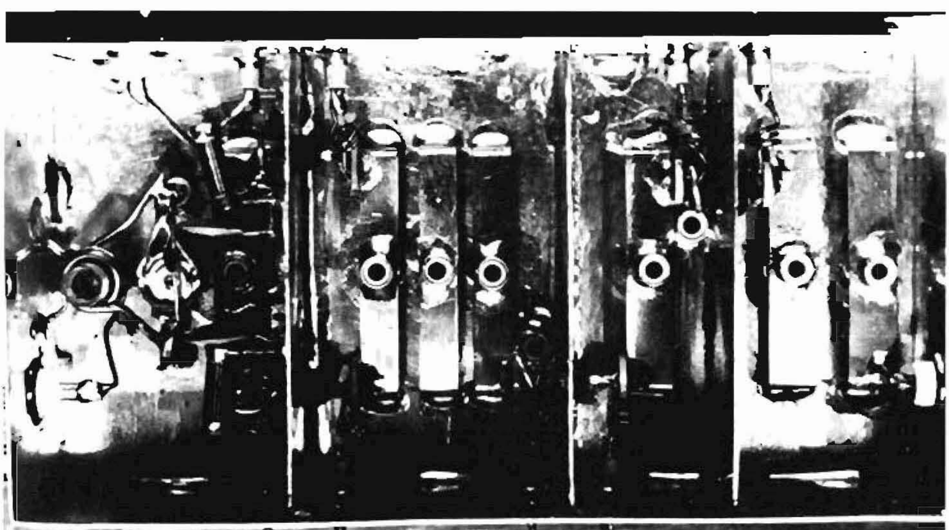

Fig. 7: Photograph of the author's prototype of module DF5QZ 002

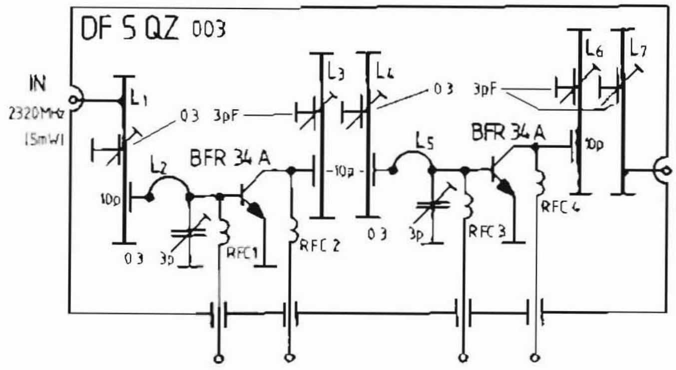

Fig. 8: Two-stage linear amplifier for approx. 60 mW in the 13 cm band

with the aid of the core of inductance L 1 and the circuit capacitance. Finally switch off the 2 m carrier and adjust the quiescent currents of the transistors to approximately 10 mA.

Switch on the 2 m signal again and measure the voltage drop across the collector bias resistor of the first amplifier transistor (point 6). The collector circuit of the push-pull mixer, the filter circuit, and the input network of the first amplifier should now also be aligned for maximum voltage drop

Also align the second amplifier stage. Attention should be paid that one does not align this to the oscillator frequency. All circuits are sharp enough to be aligned cleanly to the required, local oscillator, or image frequency! The rule of thumb is: The required frequency results with the trimmer virtually at minimum capacitance

A sensitive power-meter or indicator suitable for the frequency should be used for optimizing this module. The balance of the mixer is aligned for best oscillator signal suppression with the aid of the wattmeter. The most favorable values can, however, only be obtained with the aid of a spectrum analyzer. The measured spurious suppression amounted to 45 dB, and the output power was 5 mW

The intermediate frequency of 144 MHz used was a disadvantage. As previously mentioned, the 16th harmonic of this band falls into the 13 cm band. This unwanted effect could be avoided easily by using a different IF (such as the 70 cm band). However, if a spectrum analyzer is available, this harmonic of the 2 m signal can be completely suppressed with the aid of the 2 m circuit and the mixer operating points

With respect to the output power, it is possible using this output power to communicate via a transponder at a distance of 35 km (projected by DC0DA and DF5QZ). The input frequency was 2320.13 MHz, the output frequency 432.75 MHz. The author's signal was 45 dB above noise and was able to drive the transponder fully. The mixer operates stabily without any tendency to oscillation

3. LINEAR AMPLIFIER WITH TWO BFR 34 A

This low-power amplifier is equipped with 2 BFR 34A and is designed to be as selective as possi-

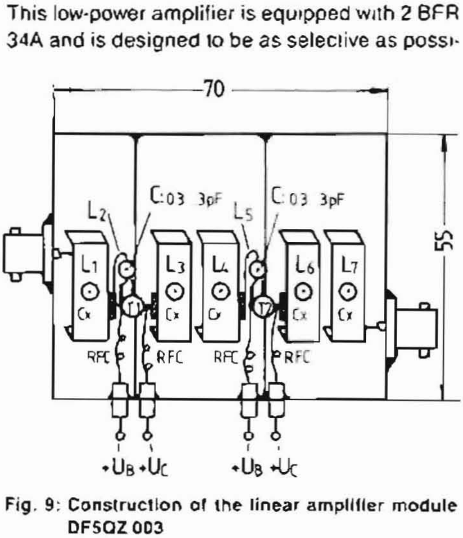

Fig. 9: Construction of the linear amplifier module DF5QZ 003

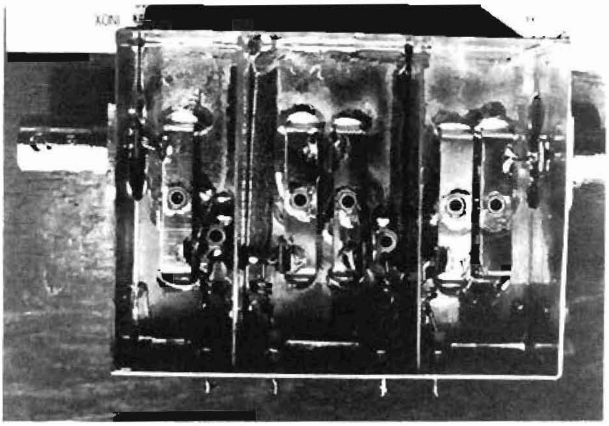

Fig. 10:
Photograph of the author's prototype DF5QZ 003

ble and to simultaneously provide a high, linear gain. These demands can only be satisfied when using chamber-type construction and when using air-spaced striplines. The construction is therefore identical to that of the 2-stage amplifier in the mixer module 002. The SHF-circuit is shown in **Figure 8.**

The bias voltage supply is carried out according to the circuit diagram given in Figure 5. A sketch given in **Figure 9** and the photograph of the author's prototype shown in **Figure 10** give an impression of the construction. The arrangement of the circuits and the chambers is not critical, however, the base connection of the transistors to the trimmers of the associated matching circuit should be kept as short as possible.

3.1. Component Details

L 1, L 3, L 4, L 6, L 7: Brass strips, 6 mm wide, 35 mm total length, bent down 4 mm at both ends (90°)

L 2, L 5: Bent from 1 mm dia. silver-plated copper wire wound on a 3.5 mm former, height 8 mm.

Trimmers (7 pcs): ceramic miniature spindle trimmers, 0.3-3 pF (Philips)

Metal box: 72 × 57 × 30 mm

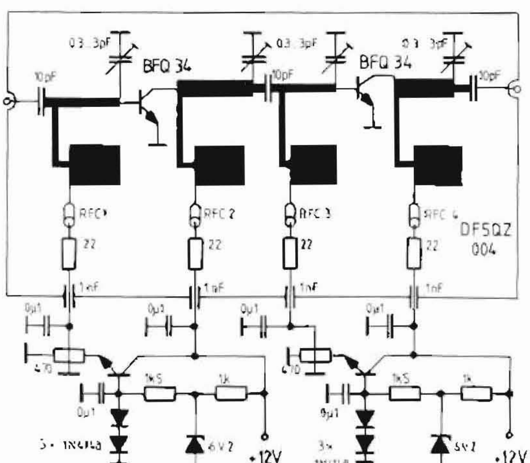

Fig. 11:
Two-stage linear amplifier for approximately 600 mW in the 13 cm band

3.2. Alignment

Firstly, adjust the quiescent currents to approximately 10 mA and connect a power-meter or other indicator to the output. A signal of approximately 5 mW is now connected from the mixer module 002 to the amplifier module 003. The voltage drop across the two collector bias resistors should now be measured again, and the resonant circuits aligned for maximum reading. The wattmeter should finally indicate approximately 60 mW. The gain of this module was measured to be 12 dB, and the 3 dB bandwidth to be 23 MHz.

4. DRIVER STAGE

Unfortunately, there are virtually no cheap power transistors for the frequency range around 2500 MHz. A possible type was given in (4). The layout of the PC-board described there was modified at one position, and then tested together with the transistor types BFQ 68 and BFQ 34. Whereas the BFQ 34 provided positive results, it was found that the BFQ 68 was unsuitable for use on this board. It seems that the S-parameters of this type differed greatly, which meant that matching could not be obtained.

On the other hand, the BFQ 34 provided a gain of

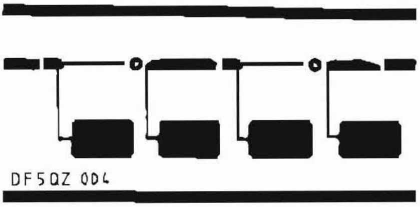

Fig. 12: Single-coated epoxy PC-board for the linear amplifier equipped with two BFQ 34

5 to 6 dB at 2.3 GHz, and thus an output power in the order of 0.5 W. It was therefore decided to construct the two-stage driver equipped with two BFQ 34, which provided the stable 10 dB gain as was expected. (see **Figure 11**)

4.1. Construction

The two-stage driver amplifier for 2300 MHz equipped with two BFQ 34 is accommodated on PC-board DF 5 QZ 004 (see **Figure 12**). This board is made from epoxy glassfibre material (G 10) and its dimensions are 108 mm × 52 mm.

This board can be fitted into a metal box, whose dimensions are 110 × 55 × 30 mm. The two networks for adjusting the quiescent currents are built up on a piece of Vero board outside of the case (see **Figure 13**). The contact of the transistor bolts to the base plate of the case is sufficient

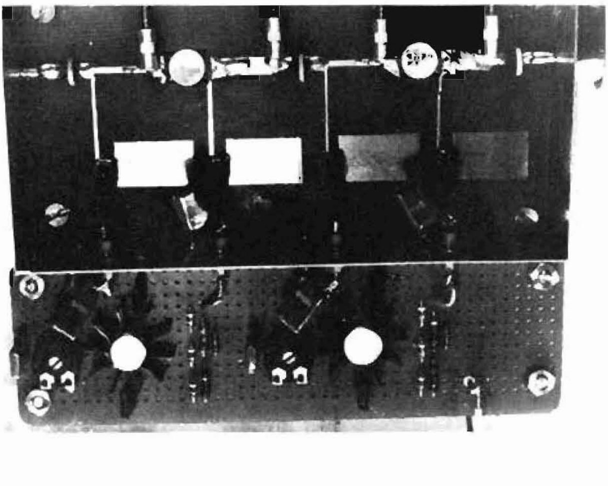

Fig. 13: Photograph of the author's prototype DF5QZ 004

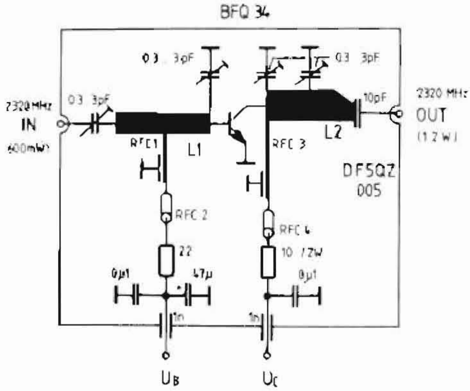

Fig. 14: 1 W power amplifier for the 13 cm band DF5QZ 005

for cooling. The collector and base connections of the transistors should be shortened and cut with the aid of scissors before soldering into place. The four chokes are ferrite beads placed over the connection wires.

4.2. Alignment of the Driver

The quiescent current of both transistors is adjusted to 140 mA. The output should now be connected to a power meter. The input signal is now connected, and the spindle trimmers aligned for maximum output power. With an input power of 60 mW, it is possible to obtain an output power of 600 mW, as was measured in the author's prototype. This allows a tube amplifier such as (2) to be driven to approximately 6 W. Since the construction of such a tube amplifier requires a lot of metal work, an attempt was made to increase the output power further using the relatively inexpensive BFQ 34

5. POWER AMPLIFIER

The transistor BFQ 34 was examined at higher drive levels with the aid of an adjustable 2320 MHz power source. The result was that the efficiency of this transistor ceases at an output power of 1.2 to 1.5 W. The parallel connection of two such BFQ 34 did not result in any noticeable success.

In the author's opinion, a printed construction is not suitable to obtain the determined 3 dB gain in the power range over 0.5 W. For this reason, the matching links were once again made in air-spaced stripline technology. **Figure 14** shows the circuit diagram, **Figure 15** the construction, and **Figure 16** the photograph of the author's prototype.

The transistor is screwed to the base; a heat sink made out of 5 mm thick aluminium plate having the same dimensions as the case is used for cooling. The hole around the transistor is carefully sawn out with the aid of a fretsaw, so that the base and emitter connections do not touch the base plate.

5.1. Components

L 1: Brass strip 6 mm wide, 15 mm long, spaced 4 mm over the base plate

L 2: Brass strip, 10 mm wide, 25 mm long; collector end bent down 4 mm, other end

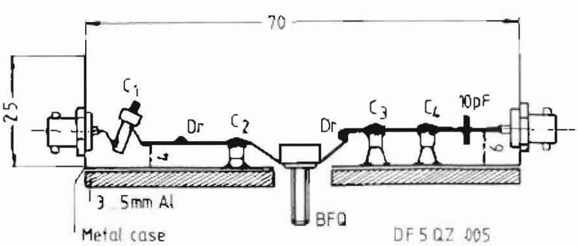

Fig. 15: Construction on the base of a metal case

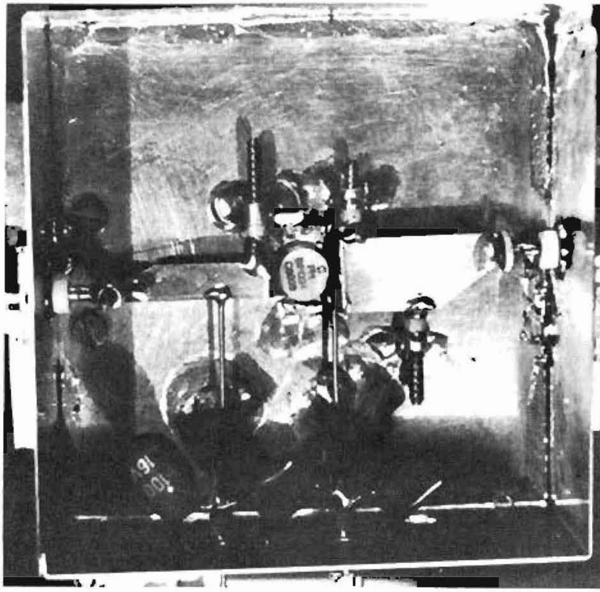

Fig. 16:
Photograph of the author's prototype 1 W power amplifier DF5QZ 005

should be cut as shown in Figures 14 and 16; mounted 6 mm over the base plate.

RFC 1: 1 mm dia silver-plated copper wire, 10 mm long

RFC 2, RFC 4: Ferrite bead

RFC 3: 2 mm dia silver-plated copper wire, 10 mm long

Trimmer: 4 ceramic miniature spindle trimmers, 0.3 – 3 pF (Philips)
C 1 mounted between the connector and L 1 self-supporting; C 2 – C 4: for horizontal mounting.

Metall case: 74 × 74 × 30 mm
Base and collector voltage supply: As in the case of driver DF5QZ 004.

5.2. Alignment of the Amplifier

Connect a power meter to the output, and align a quiescent current to 140 mA. Connect the signal at the input and align for maximum output. In the author's prototype, 1 to 1.3 W were obtained with a drive level of 500 to 600 mW.

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